SEARCH FOR THE Θ^+ IN PHOTOPRODUCTION ON THE DEUTERON *

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A high-statistics experiment on a deuterium target was performed using a real photon beam with energies up to 3.6 GeV at the CLAS detector of Jefferson Lab. The reaction reported here is for $\gamma d \to p K^- K^+ n$ where the neutron was identified using the missing mass technique. No statistically significant narrow peak in the mass region from 1.5-1.6 GeV was found. An upper limit on the elementary process $\gamma n \to K^- \Theta^+$ was estimated to be about 4-5 nb, using a model-dependent correction for rescattering determined from $\Lambda(1520)$ production. Other reactions with less model-dependence are being pursued.

1. Introduction and Results

The search for pentaquarks, made from four quarks and one antiquark, has captured the interest of the nuclear-particle physics community since the announcement of a possible experimental signal by the LEPS Collaboration[1]. Since then, there have been many results published, some positive and some null, and the reader is referred to a recent review[2] for more details.

Here, we focus on the reaction $\gamma d \to p K^- K^+ n$ which was previously published[3] but with low statistics. The present results are for a high-statistics experiment, known as "g10", carried out using the same detector, the CEBAF Large Acceptance Spectrometer (CLAS) at Jefferson Lab. The experimental setup is the same as Ref. 3, known as "g2a", except for two items: (1) the beam energy was increased, allowing photons from 0.9-3.6 GeV; (2) the target was moved upstream by 25 cm to increase the acceptance for negative particles. The data analysis and event selection cuts used in the present analysis are the same as Ref. 3, and the photon energy range has been restricted (by software) to match as closely as possible the conditions of Ref. 3. In this sense, the analysis is a "blind" analysis, so that no bias was introduced in the high-statistics result.

In the g10 experiment, the data was taken at two magnetic field settings of the CLAS torus coils. At both field settings, a luminousity of about 25 pb^{-1} was collected, which is nearly 10 times the luminousity of the previous g2a data[3].

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Only the high-field data will be presented, which matches the conditions of the g2a data, although the results from the low-field setting are found to be similar. After restricting the photon energy range to be the same as g2a, the g10 experiment had 5.9 times the luminousity of the g2a experiment. A comparison of the two experiments is shown in Fig. 1, where the missing mass of the pK^- system (equal to the mass of the nK^+ system, from possible Θ^+ decay) is plotted. The vertical scale shows the number of counts in the published g2a data[3] and the g10 data have been scaled by the luminosity, shown by the solid histogram.
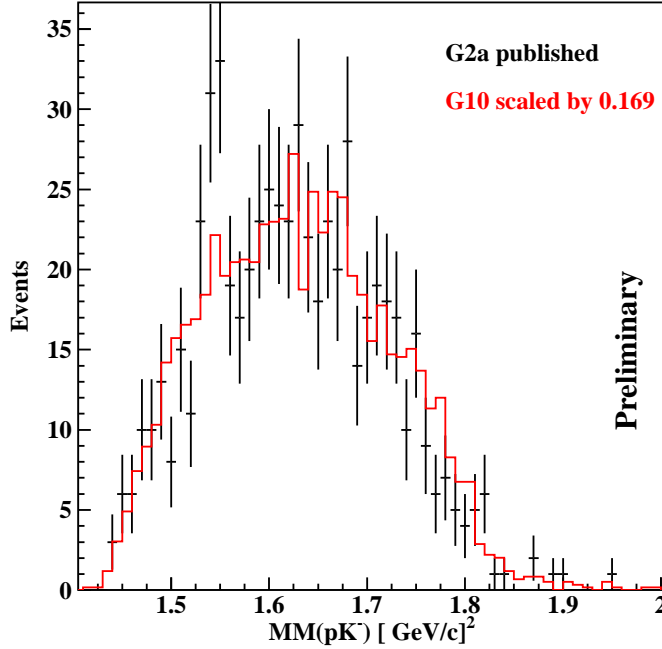

Figure 1.   Missing mass of the pK^- system for the reaction $\gamma d \to pK^-K^+n$ measured at CLAS. The points with error bars is from Ref. [3], and the solid histogram shows the present (high-statistics) results, scaled down by the factor shown.

Clearly, the peak seen in the g2a data is not reproduced by the g10 data. Using the g10 data as a guide to the background shape, the probability of a fluctuation of the amount seen at 1.54 GeV in the g2a data is found to be about 3-σ (three standard deviations). The claim of a 5-σ statistical significance in Ref. 3 was due to a lower estimate of the background. We note that the g2a data fluctuate downward from the g10 shape on either side of the 1.54 GeV "peak". In hindsight, we see that the evidence for the Θ^+ claimed in Ref. 3 is due to a combination of an

underestimate of the background shape and a statistical fluctuation in the region of 1.54 GeV. These results show the importance of high statistics, along with a "blind" analysis procedure where the event selection criteria are determined before the experiment is done.

It is now a straight-forward procedure to fit the g10 mass spectra with an overall background shape (using a third order polynomial). Using a fixed background and fitting a gaussian (with a 6 MeV width, equal to the CLAS resolution) across the mass spectrum, an upper limit on the number of counts in the mass region of 1.54 GeV is found. Using the luminosity, along with and the gaussian fit results and a detector acceptance from Monte Carlo, an upper limit on the *measured* reaction on deuterium has been calculated. We assume a uniform angular distribution for Θ^+ production, even though the CLAS detector does not measure particles at forward angles (the angle is momentum-dependent but roughly 15°-20° lab for K^- and roughly 8°-10° lab for the K^+). This may not be a valid assumption if the Θ^+ is produced primarily at forward angles, as suggested by the LEPS data[1].

An upper limit on the cross section for the elementary reaction $\gamma n \to K^- \Theta^+$ is desired. Of course, the reaction we measured was on deuterium, not a free neutron. In order to convert from the measured result to the elementary reaction, a theoretical model must be used. The model is complicated by the fact that the proton is detected in CLAS, which requires it to have a momentum of > 350 MeV to exit the liquid deuterium target. Ideally, the proton in the deuterium target would be a spectator to the elementary reaction, having nearly zero momentum (smeared by Fermi momentum). In the g10 experiment, the proton must gain momentum by final state (rescattering) reactions. In order to estimate the rescattering correction, we look to the mirror reaction $\gamma p \to K^+ \Lambda(1520)$. In this mirror reaction, the neutron would be a spectator, and its momentum is found in g10 by the missing momentum. By cutting on the neutron momentum above 350 MeV, the rescattering probability of the mirror reaction is found to be about 0.10 ± 0.01. Assuming a similar correction for rescattering in Θ^+ production on deuterium, the cross section for the elementary process is estimated at 4-5 nb.

The model dependence in the above cross section estimate is undesirable but unavoidable. One could imagine other ways to do the rescattering correction, such as using the tail of the Fermi momentum above 350 MeV for the proton in deuterium. In this case, the upper limit is increased by a factor of 5, to 20-25 nb. Both estimates, one using the $\Lambda(1520)$ model and the other using the Fermi tail, are shown as a function of the nK^+ mass in Fig. 2. Other models might suggest a bigger rescattering probability, thus reducing the upper limit. Clearly, a measurement without a rescattering correction would be better. For example, the reaction $\gamma d \to K^- \Theta^+ p$ where the proton is not detected, and the decay $\Theta^+ \to K^0 p$ is measured, has less model dependence to deduce the elementary reaction cross section. Further analysis of the g10 data is in progress and more results are expected soon.
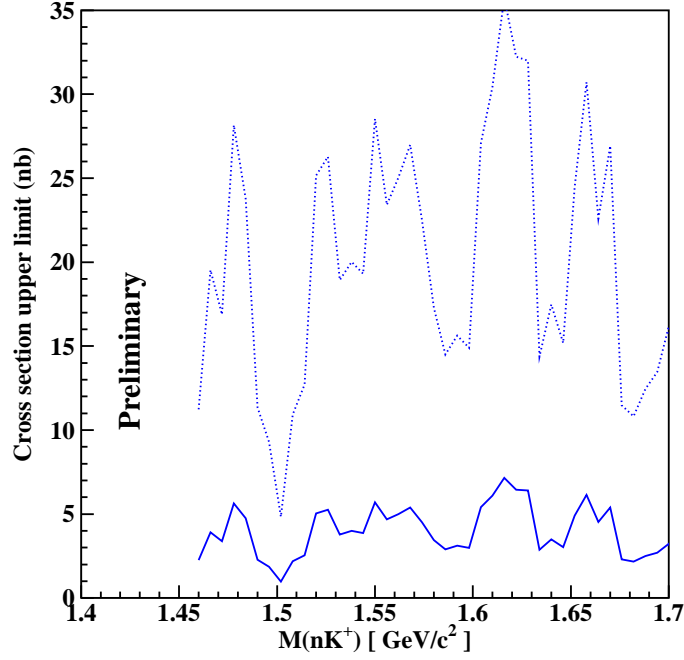
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Figure 2.   Preliminary upper limit for the elementary reaction $\gamma n \to K^- \Theta^+$ using the $\Lambda(1520)$ for the rescattering correction (lower line) and the Fermi momentum tail for the correction (dotted upper line). All curves come from fitting a fixed-width gaussian on top of a fixed polynomial background, using the same mass spectrum from the g10 experiment.

2. Summary

The exclusive reaction $\gamma d \to p K^- K^+ n$ was measured at CLAS with high statistics. No evidence for a narrow peak in the nK^+ mass spectrum was observed, contrary to earlier low-statistics results[3]. A *model dependent* upper limit for the cross section in the elementary reaction $\gamma n \to K^- \Theta^+$ was estimated to be about 4-5 nb, using the $\Lambda(1520)$ as a model for the rescattering.

References

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